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CORRELATED CHARACTERS IN MAIZE BREEDING

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INTRODUCTION

The study of correlations as an aid to plant breeding was at one time thought to be full of promise, but in recent years little use has been made of correlations by practical workers. From this fact it might appear that the early hopes were unwarranted, and that correlation is a factor of little or no importance. It must be conceded that the elaborate calculations of correlation coefficients have in few instances proved of value to the practical breeder, yet it must be admitted on reflection that nearly all successful breeding has in reality been made possible by the fact that correlations exist.

In plant breeding the improvement and preservation of varieties has largely resulted from the ability of the breeder to recognize desirable types, and the existence of definite types is in itself a manifestation of the correlation of characters. The existence of types must mean that there are many individuals that present approximately the same combination of characters, and this is exactly what correlation implies. The characteristics of the desired type are recognized by the breeder even though they may not be formulated, and varieties are seldom established by selection confined to a single character. If the study of correlations has appeared to have little bearing on plant breeding, it must be that we have been studying the wrong characters or studying them in the wrong way.

In the improvement of maize varieties (*Zea mays*), as with other plants, the recognition of types has been an important factor. The selection, however, has been almost entirely confined to the ear. In a field of any commercial variety it is easy to recognize differences in the plants, but even after long familiarity with the variety the plants refuse to be classified into distinct groups. This difficulty in recognizing types among maize plants greatly increases the difficulty of breeding this crop.

The lack of recognizable types in maize is very different from the condition that obtains, for example, in cotton (*Gossypium* spp.). With cotton,

skilled breeders are able to detect deviation from type even in the early stages of development and the practice of roguing can proceed with certainty. It appears that when a cotton plant deviates from type it deviates in a more or less definite way and in many particulars, or, in other words, there are a number of coherent or correlated characters.

It seemed desirable to determine whether the difficulty in recognizing types in maize is due to a lack of familiarity with the plants or whether there is a fundamental difference between the heredity of maize and that, for example, of cotton.

In the seed characters of maize a definite correlation has been found between the color of the aleurone and the texture of the endosperm (Collins and Kempton, 1913). Correlations have also been noted between the color of the silk and the color of the anthers (Webber, 1906), and between the color of the seed and the color of the cob, dwarfness and broad leaves, and between stamens in the ear and club-shaped tassels (Emerson, 1911). There was, therefore, abundant reason for suspecting that the difficulty of recognizing types among maize plants might be due to a lack of sufficient discrimination, and it was with the idea that correlations were the rule rather than the exception that the present experiment was undertaken. Contrary to expectation, the results give evidence that for the varieties and characters studied there is almost a complete absence of genetic correlations.

CLASSIFICATION OF CORRELATIONS

Correlations may be classified in a great variety of ways and with almost any degree of refinement. As with any classification of organic activities, no particular grouping can be made to serve all purposes, for it is necessary to divide the subject in different planes.

For purposes of the present discussion correlations, or the mutual relations of characters, are divided into three main groups, to which the names "physical," "physiological," and "genetic" may be applied.

PHYSICAL CORRELATIONS are those in which the relation is obviously causal. In many instances correlations of this kind are little more than different names for the same phenomenon, or parts of the same phenomenon, as when increased weight is correlated with increased height. In physical language one of the characters would be described as a function of the other.

PHYSIOLOGICAL CORRELATIONS are those where both characters are the result of the same physiological tendency, as when long internodes in the main stalk are correlated with long internodes in the branches. This may be looked upon as a general tendency to elongated growth that is manifested in different parts of the plant.

GENETIC CORRELATIONS cover the large residue of correlations, the nature and causes of which are questions of controversy, but which are

associated with the method or mechanism of heredity. An example of this type of correlation is shown in the association of yellow petals and deeply lobed leaves in Egyptian \times Upland cotton hybrids.

This classification differs from those proposed by Webber (1906) and East (1908) chiefly in placing physical correlations outside the pale of biological correlations. Most of those correlations classed by Webber as morphological would here be considered as physical. This distinction is made because it seems to the writer that the relation between length and weight, for example, is inherent in the properties of matter and is not a biological phenomenon. Certainly a relation of this kind would be found in stones or any inanimate objects selected at random.

Since physiological functions are always directly or indirectly induced by or at least associated with environmental stimuli, Webber's environmental and physiological correlations are here combined. That the examples of physiological correlations cited by Webber are reverse or negative correlations need not confuse the issue, since by simply stating the relation in other terms the correlations can be made to appear as positive.

The distinction between physiological and genetic correlations may not always be easy to apply, and the apparent need of it may disappear entirely with a more complete knowledge of inheritance and methods of growth. For the present, however, the distinction will be useful even if physiological correlations are confined to pure lines or asexually propagated stocks where differences in inheritance can be eliminated. To ascribe the long internodes of the main stem and branches to the activity of a single determiner or gene is hardly less futile than to offer the same explanation for the correlation between the length and weight of inanimate objects. If the one is inherent in the properties of matter, the other is inherent in the properties of plants.

All examples of genetic correlation are exceptions to the third law of Mendel, which implies that characters are redistributed in the perjugate generations of a hybrid in accordance with the laws of chance. Conversely, all instances in which Mendelian ratios, other than the 3 to 1 ratio of a monohybrid, are followed with exactness demonstrate the action of this third law and the absence of correlations among the factors which make up the characters. It should be kept in mind, however, that multiple hybrid ratios have seldom been determined with any great degree of accuracy, so that correlations, unless of a pronounced type, would escape detection.

The significant factor in genetic correlations is the grouping of the characters in the ancestry and not the inherent properties of the characters themselves. Thus, when colored aleurone and horny endosperm are found to be correlated in the progeny of a hybrid, involving colored and white aleurone and horny and waxy endosperm, it does not indicate

any attraction between colored aleurone and horny endosperm, but rather that one of the parents had colored aleurone and horny endosperm, while the other parent had white aleurone and waxy endosperm. This tendency for parental combinations to reappear has been called "coherence," and, so far as known, all genetic correlations thus far recorded are of this nature.

Many investigations have been devoted to correlations in agricultural plants, but unless the special class of correlations covered by coherence is kept in mind the results are likely to be disappointing to the breeder. Cylindrical ears of maize may be correlated with high yield in one population and the opposite result be reached in another case, depending on whether these characters were introduced into the population under investigation from the same parent or from different parents.

There are doubtless many physiological correlations that may be detected by elaborate measurements, but unless the observations are confined to asexually propagated groups or to those of which the ancestry is kept in carefully studied, there will always remain the uncertainty whether there is an inherent physiological relation between the development of the two characters or whether the correlation is the result of ancestral combinations. The distinction is not without practical importance, for a physiological correlation can not be reversed by any direct means at the disposal of the breeder—that is, without evoking mutation or some form of evolutionary change—while, if the correlation is genetic, the relation between the characters may usually be reversed by a few generations of selection in the desired direction.

Two principal theories have been advanced to explain genetic correlations. These are the theory of reduplication (Bateson, Saunders, and Punnett, 1906) and the theory of linkage developed by Morgan and his students (1915) from studies of the fruit fly *Drosophila ampelophila*. Both of these theories deal with characters which are alternative, both having been derived from the study of Mendelian inheritance.

With the idea that continuous inheritance is to be looked upon as a complicated form of alternative inheritance, it should be interesting to learn what light the study of genetic correlations between characters that are blended in inheritance may throw on the theories of reduplication and linkage. The experiments described below constitute a preliminary attempt to extend the study of genetic correlations to characters that are continuously inherited.

METHODS OF DISTINGUISHING BETWEEN PHYSIOLOGICAL AND GENERIC CORRELATIONS

To determine with certainty that a given correlation is physiological and not genetic, it would be necessary to demonstrate the existence of the correlation in material where all the individuals possessed the same

hereditary tendencies with respect to the characters studied. Theoretically this is only possible in asexually propagated groups. Approximately pure lines may be obtained where self-pollination is possible, so that if correlations are found they may with assurance be considered physiological. In maize, however, even to approximate pure lines produces such abnormal conditions that some other method of study must be sought.

Even in maize it would seem that the question might be approached by comparing the degree of correlation in types or varieties having a relatively restricted ancestry with that observed in the perjugate generations of hybrids between two contrasting forms.

An equally satisfactory method is to compare the degree of correlation in the first or conjugate generation of a hybrid with that of the perjugate generations. Where the conjugate generation is all descended from a single cross, the gametic differences should be no greater than self-pollinated progenies of the parents.

Unfortunately in our experiment the number of first-generation individuals was too limited to detect any but relatively large correlations. Wherever data were available, additional evidence has been presented from the behavior of the original varieties. Although a large number of plants of both parent varieties have been grown and measured, the data have been secured in different localities and in different years, a fact that renders many of the measurements unavailable for these studies.

DESCRIPTION OF MATERIAL

The hybrid that afforded the data for the present paper was a cross between Waxy Chinese and Esperanza, two varieties of maize separated by a number of definitely contrasted characters. The hybrid was made at Lanham, Md., in 1908.

The peculiarities of the Waxy Chinese variety (Pl. LV-LVI) have been described elsewhere (Collins, 1909).

The particular plant used as female parent of the hybrid was grown from the original seed imported from China. The individual notes taken in 1908 give the following details:

Height, 167 cm. Length of fifth leaf from the top, 83 cm. Width of fifth leaf, 9 cm. Leaf sheath smooth. Nodes above the ear, 4. Suckers, 0. Plant rather open, but distinctly one-sided.

The Esperanza variety belongs to a peculiar type of maize that appears to be confined to the table-lands of Mexico, the *Zea hirta* of Bonafous (1829). This variety was obtained in 1906 from Esperanza, Pueblo, Mexico, by Mr. H. Pittier, of the Bureau of Plant Industry (Pl. LVIII and LIX).

The plant that was the male parent of the hybrid was raised from seed grown at Lanham, Md., in 1907. Regarding the 1907 plants, the notes

state that all were typical of the hairy Mexican type, ranging from 150 to 210 cm. in height. The notes recorded for the 1908 plant used in making the hybrid state that it was typical of the variety except for a general shortening of the internodes. It was 105 cm. high, had three tassel branches, four nodes above the ear, and the fifth leaf from the top measured 83 by 14 cm.

Sixteen first-generation plants were grown in 1909. Three pure-seed ears that provided seed for the second generation are designated as No. 1, 2, and 3. Four plants entered into the parentage of these three ears. No. 1 and 2 were reciprocals. No. 1 resulted from pollinating plant 225 by plant 226. No. 2 by pollinating plant 226 by plant 225. No. 3 was the result of pollinating plant 262 by plant 263. The ears on all three of the first-generation plants that produced ears 1, 2, and 3 showed the usual mixture of waxy and horny seeds that result from crossing the Waxy Chinese and a corneous or horny variety. The notes taken on the four first-generation plants are presented in Table I.

TABLE I.—Description of four first-generation maize plants grown in 1909

Plant No.	225	226	262	263
Height.....cm..	222	228	212	230
Number of tassel branches.....	20	18	17	17
Nodes above the ear.....	5	5	5	5
Length of fifth leaf.....cm..	14	13	14	13.5
Width of fifth leaf.....mm..	63	76	86	88
Exsert of tassel.....	0	0	0	(a)
Arrangement of leaves.....	(b)	(b)	(b)	(c)

^a Exserted.

^b Scorpioid.

^c Neither monostichous nor scorpioid.

The final planting was made in 1914. The remnant of seed from the original hybrid ear was planted and furnished 31 first-generation plants. Six rows of approximately 30 plants each were secured of second-generation plants, one row from waxy, and one from the horny seeds of each of the first-generation ears.

The means of the characters measured are given in Table II, and the coefficients of variation in Table III.

TABLE II.—Mean of different characters in first- and second-generation maize plants

Character.	First generation.	Second generation.			
		Ear 1.	Ear 2.	Ear 3.	
Height.....	213.0 ± 2.56	Plants from waxy seed.	Plants from horny seed.	Plants from waxy seed.	Plants from horny seed.
Length of panicle.....	15.0 ± .37	194.0 ± 3.32	193.0 ± 3.83	182.0 ± 4.59	185.0 ± 2.75
Length of branch.....	15.0 ± .37	13.4 ± .33	13.6 ± .29	16.5 ± .58	13.8 ± .43
Number of branches.....	28.1 ± .54	35.4 ± 1.14	35.0 ± .79	24.1 ± .40	24.8 ± .37
Number of secondaries.....	5.3 ± .31	5.9 ± .32	5.3 ± .32	3.6 ± .37	3.6 ± .41
Length of tassel.....	11.6 ± .58	4.7 ± .16	15.7 ± .06	4.2 ± .06	4.6 ± .07
Length of longest leaf.....	12.7 ± .16	11.9 ± .22	12.0 ± .17	12.5 ± .23	12.6 ± .42
Width of longest leaf.....	9.0 ± .108	9.15 ± .124	9.04 ± .177	10.9 ± .097	10.9 ± .108
Number of nodes above longest leaf.....	24.1 ± .20	8.1 ± .16	24.3 ± .27	8.3 ± .31	8.1 ± .17
Total number of nodes.....	24.1 ± .20	8.8 ± .24	7.8 ± .32	8.1 ± .38	7.5 ± .32
Number of sheaths with hairs.....	9.5 ± .17	8.4 ± .29	7.8 ± .32	6.4 ± .22	7.5 ± .32
Number of sheaths without hairs.....	4.9 ± .30	3.7 ± .39	4.8 ± .32	4.2 ± .08	4.0 ± .26
Length of hairs.....	34.0 ± .31	34.6 ± .46	32.6 ± .33	31.9 ± .84	35.3 ± .19
Density of spikelets.....	9.3 ± .12	10.1 ± .08	9.8 ± .14	10.2 ± .14	9.0 ± .14
Number of erect blades.....	44.3 ± .76	40.5 ± 6.10	37.0 ± .86	42.5 ± .99	36.3 ± .64
Angle of tassel axis.....	44.3 ± .76	40.5 ± 6.10	37.0 ± .86	42.5 ± .99	36.3 ± .64
One-sidedness.....	18.4 ± .38	3.9 ± .33	4.9 ± .37	4.2 ± .39	4.5 ± .31
Number of rows, second ear.....	17.2 ± .23	18.0 ± .28	19.8 ± .43	18.3 ± .36	17.1 ± .35
Number of husks, upper ear.....	12.9 ± .25	11.3 ± .40	11.0 ± .39	11.3 ± .31	11.8 ± .41
Number of husks, second ear.....	12.7 ± .25	11.3 ± .40	9.7 ± .25	11.7 ± .38	11.8 ± .41
Exsert of tassel.....	3.62 ± .38	3.17 ± .40	3.05 ± .33	2.68 ± .45	3.53 ± .57

TABLE III.—Coefficient of variation of characters in first- and second-generation maize plants

Character.	First generation.	Second generation.					
		Ear 1.		Ear 2.		Ear 3.	
		Plants from waxy seed.	Plants from horny seed.	Plants from waxy seed.	Plants from horny seed.	Plants from waxy seed.	Plants from horny seed.
Height.....cm.	8.0±0.7	14.7±1.5	13.0±1.1	14.5±1.4	19.0±1.8	14.9±1.8	17.0±1.8
Length of branching space.....cm.	19.3±1.8	20.4±1.9	19.6±1.8	18.8±1.5	18.3±1.7	22.0±2.5	20.6±2.2
Length of central spike, cm.	14.5±1.3	19.7±2.0	15.2±1.5	13.8±1.4	17.5±1.6	11.6±1.4	9.7±1.0
Number of branches.....	26.3±2.5	27.0±2.7	25.2±2.4	17.5±1.7	22.0±2.1	22.0±2.7	29.1±3.3
Number of secondaries.....	46.4±4.9	40.4±4.2	43.4±4.5	43.6±4.7	41.9±4.6	62.0±9.1	76.2±11.6
Number of nodes above ear.....	14.4±1.3	17.4±1.7	17.3±1.5	9.6±1.0	14.3±1.4	8.3±.9	10.4±1.1
Length of longest leaf, cm.	4.4±.4	8.1±.7	8.2±.7	6.7±.8	9.7±1.0	8.7±.9	9.4±1.0
Width of longest leaf, cm.	10.0±2.5	10.7±1.0	15.1±1.3	10.4±1.0	8.2±.7	12.8±1.3	17.4±1.9
Ratio of length to width.....	9.3±.8	11.0±1.0	10.7±1.0	10.2±1.0	10.5±.9	17.9±1.4	13.7±1.3
Number of nodes above longest leaf.....	12.1±1.1	18.4±1.7	17.5±1.6	14.2±1.4	21.8±1.9	18.8±2.0	13.1±1.4
Total number of nodes.....	6.2±.6	10.9±1.1	.....	6.8±.7	9.1±.9	8.0±1.0	5.7±.7
Number of sheaths with hairs.....	14.1±1.2	26.2±2.5	19.8±1.8	29.4±3.2	26.4±2.5	23.3±2.5	19.1±2.1
Number of sheaths encircled by hairs.....	100.0±15.0	170.0±42.0	83.4±11.1	169.0±42.0	130.0±25.0	225.0±78.2	175.0±50.0
Length of hairs.....mm.	22.4±2.0	19.7±1.9	17.2±1.5	18.5±1.9	10.4±1.0	18.0±1.0	21.3±2.3
Density of spikelets.....	10.3±2.0	10.2±1.9	18.1±3.5	89.7±2.1	10.8±1.9	21.6±2.4	24.8±2.8
Length of glumes.....mm.	10.7±1.0	9.1±.9	6.8±.9	10.2±1.0	10.5±1.0	9.1±1.0	12.5±1.7
Number of erect blades.....	57.4±6.9	68.7±9.8	66.9±9.5	60.6±10.1	75.0±9.8	54.2±8.6	57.3±7.5
Angle of tassel axis.....(°)	67.2±8.9	98.2±16.5	60.7±7.9	74.4±10.4	89.5±13.1	77.9±10.8	101.0±18.6
One-sidedness.....	53.6±6.4	48.8±5.7	58.5±7.5	49.6±6.6	52.6±6.4	46.4±5.9	47.8±6.3
Number of rows, upper ear.....	13.7±1.4	20.7±2.5	17.2±1.7	13.8±1.8	13.7±1.4	12.7±1.4	15.3±1.9
Number of rows, lower ear.....	18.6±2.0	15.5±2.5	19.9±3.3	12.4±1.6	15.0±2.0	13.8±1.7	13.0±1.9
Number of husks, upper ear.....	15.1±1.4	24.6±2.6	20.6±2.0	18.8±1.0	20.2±2.1	15.3±1.8	22.7±2.6
Number of husks, lower ear.....	19.3±2.0	23.1±3.6	14.4±2.2	11.6±1.8	19.5±2.4	15.8±2.5	18.0±2.5

A comparison of these tables shows that the first-generation plants exceeded the second-generation plants in height, length of branching space, length of central spike, length and width of longest leaf, number of nodes above the longest leaf, number of leaf sheaths with hairs, and number of single-ranked blades. The second-generation plants exceeded the first-generation plants in the number of tassel branches. In the other characters there was no significant difference between the means of the first and second generation plants.

The first-generation plants were distinctly less variable than the second-generation plants in height, length, and width of longest leaf, number of nodes above the longest leaf, total number of nodes, and number of leaf sheaths with hairs. The first-generation plants were more variable with respect to the length of the tuberculate hairs and density of spikelets.

The least variable character measured was the length of the longest leaf. The total number of nodes was also comparatively uniform. The very high coefficient of variation for the number of sheaths encircled by hairs results in part from the alternative nature of this character.

In the progeny of the reciprocal ears 1 and 2 there are no really significant differences. The progeny of ear 3, however, which descended from entirely different first-generation plants, shows a number of differences from the remainder of the second-generation plants.

Although the average height of the plants from all these ears is practically the same, the progeny of ear 3 shows smaller values for a number of other dimensional characters. The number of branches, primary and secondary, length of leaf, total nodes, length of glumes, and number of rows of grains are all slightly lower. With the exception of length of leaf and length of glumes, these differences might be interpreted as indicating a more pronounced development of the *Esperanza* characters. The same may be said of the exert, which is higher in ear 3. In the development of tuberculate hairs, on the other hand, the progeny of ear 3 was decidedly more like the Chinese variety.

In addition to the measurements given in Tables II and III, there are a number of differences that deserve to be more fully discussed.

HAIRS ON THE LEAF SHEATH

Perhaps the most striking difference between the varieties is the covering of the leaf sheaths. In the Chinese variety the leaf sheaths are similar to those of the ordinary types of maize. The surface is smooth, except for fine spicules, which occur especially over the fibrovascular bundles. The spaces between the fibrovascular bundles are crossed by numerous diagonal ridges or cross veins irregularly arranged and usually discontinuous at the fibrovascular bundles. These cross veins with the fibrovascular bundles cover the surface of the sheath with a coarse reticulum.

In the *Esperanza* variety the cross veins of the sheaths are absent or confined to the seedling leaves, and the spaces between the bundles are occupied by tubercles, each bearing a long hair (Pl. LVIII). These tuberculate hairs are absent from the sheath of the first six to eight leaves of the seedling. They appear abruptly and may cover the entire surface of the first sheath on which they appear. The hairs are from 3 to 5 mm. long, and the tubercle is approximately $\frac{1}{2}$ mm. wide and of the same height.

In the Waxy Chinese variety tuberculate hairs are completely absent (Pl. LVI, fig. 2). As in all varieties, there is a small area closely confined to the throat of the sheath that is clothed with long hairs. It is not clear whether these hairs are homologous to the tuberculate hairs of the *Esperanza* variety or not. Even considering these hairs at the throat of the leaf sheath in the Waxy Chinese variety as of the same type, the two varieties are completely separated, with not even an approach to overlapping forms. In the hybrid and its progeny three methods of measuring the degree of hairiness were employed:

- (1) By recording the total number of nodes with hairy sheaths.

(2) By recording the number of nodes with hairs completely encircling the sheath. In the pure Esperanza maize this usually occurred at the lowest node on which hairs were borne; or at most there was a difference of only one or two nodes. In the hybrid plants there were usually a number of sheaths with tuberculate hairs at the side, but with a narrow smooth strip at the back over the midrib.

(3) By recording the length of the longest tuberculate hairs. In all hybrid plants of both the first and second generation tuberculate hairs were present, there being no plant that resembled pure Waxy Chinese plants in this particular. The length of the hairs varied, however, in different plants, thus affording another measure of the extent to which hairs were developed.

TASSEL CHARACTERS

In the nature of the tassel the two varieties are hardly less distinct than in the covering of the leaf sheath. The Waxy Chinese variety has many branches, 15 to 30 primary branches in normally developed plants, with numerous secondaries. The Esperanza (Pl. LVII) seldom has more than 5 branches and in many plants the tassel is simple, consisting only of a large central spike. Associated with the difference in the number of branches is a corresponding difference in length of the axis or "branching space," the distance from the lowest to the uppermost branch.

In the Esperanza variety the glumes vary from 10 to 16 mm. in length with a mean of 11.7 ± 0.14 . In the Waxy Chinese variety the range is from 7 to 12 mm., with a mean of 9.2 ± 0.09 . All of the above characters were directly measured or counted.

The typical arrangement of the spikelets is also different in the two varieties. In the Waxy Chinese the arrangement on the branches is similar to that in most of the better known varieties of maize. The spikelets are paired, one pedicel and one sessile, the pairs alternating on the sides of the branch. In the Esperanza maize when branches occur the spikelets are nearly all sessile and are borne in clusters of from 2 to 5. They are also disposed on all faces of the branch instead of being confined to the sides. The arrangement of spikelets and general appearance of the branches in the Esperanza is similar to the arrangement on the central spike. One result of these differences in arrangement of spikelets is a greater crowding of spikelets in the Esperanza. As a measure of this difference the number of spikelets in the last 10 cm. of the lowest tassel branch were counted. This number is referred to as the "density of the spikelets."

TASSEL EXSERT

In the Waxy Chinese variety the base of the tassel is frequently inclosed in the uppermost leaf sheath. In the Esperanza variety the lowest branch of the tassel is usually well above the uppermost leaf

sheath in the mature plant. Differences in this particular were recorded by measuring the distance from the top of the uppermost sheath to the origin of the lowest tassel branch, the measurement being expressed as a minus quantity when the base of the branch was included in the sheath.

This character is especially subject to environmental changes. Unfavorable conditions, such as drought occurring late in the season, will prevent the elongation of the upper internodes to such an extent that all varieties may show a minus exert. Comparisons must therefore be confined to plants grown in a single season in the same locality.

The range as recorded for Waxy Chinese grown at different times is from -14 cm. to 7 cm., with the mean at -1.31 ± 0.3 . In Esperanza the range is from -3 cm. to 18 cm., with the mean at 6.07 ± 0.5 .

NUMBER OF ERECT LEAF BLADES

In the Waxy Chinese variety the upper leaf blades are held erect instead of diverging. In ordinary varieties which the Esperanza resembles with respect to this character the upper leaf blades make approximately a right angle with the axis (Pl. LV, LVII). As a measure of this character the number of erect leaf blades was recorded. For example, if the two uppermost leaves were erect and the third leaf was the first to exhibit an angle, the plant was classed as 2, with respect to this character.

Recorded in this way there would be some overlapping in the parent varieties, since in some Waxy Chinese plants even the uppermost leaf shows an appreciable angle. In reality, however, the two types are distinct, for in the Esperanza not only is the uppermost leaf never erect, but it is seldom borne at less than a right angle with the stalk.

ANGLE OF TASSEL AXIS

In the Esperanza variety the tassel is always erect. In the Waxy Chinese plant the tassel is usually curved or declined (Pl. LV, LVII). This character is variable in the Chinese, some plants having the tassel perfectly erect. The tendency, however, to an inclined tassel, as it appears in the hybrid, may properly be ascribed entirely to the Chinese variety, no similar tendency ever having been observed in any Esperanza plant. The character was measured by estimating the angle which the branching space, or that portion of the axis of the tassel between the lowest and highest branch, made with the main stalk. In the pure Waxy Chinese variety this character appears definitely associated or physiologically correlated with the following character of "one-sidedness."

ONE-SIDEDNESS

One of the most striking peculiarities of the Waxy Chinese variety of maize is the displacement of the leaf blades from the usual distichous arrangement, with the result that a number of the upper leaf blades are

borne on one side of the plant instead of alternately on opposite sides of the culm (Pl. LVI, fig. 1). Like the angle of the tassel, this character is not universally present in the Waxy Chinese plant, but, on the other hand, no tendency of this kind has ever been observed in the Esperanza variety.

When one-sided plants occur in the hybrid generations, it is therefore reasonable to assume that the character was derived from the Chinese parent. Measurements of these characters in the hybrid plants were made by recording the number of monostichous or single-ranked leaves.

A recapitulation of the more definitely contrasting characters of the two parent varieties is here presented in parallel columns:

Esperanza variety	Waxy Chinese variety
Horny endosperm.	Waxy endosperm.
Branching space short.	Branching space long.
Tassel erect.	Tassel curved.
Spikelets in clusters.	Spikelets in pairs.
Glumes long.	Glumes short.
Leaf sheaths with tuberculate hairs.	Leaf sheaths without tuberculate hairs.
Upper leaf blades horizontal.	Upper leaf blades erect.
Upper leaf blades distichous.	Upper leaf blades monostichous.

If the characters of maize were subject to coherence, the second generation of a cross between two such diverse and long-established types as Esperanza and Waxy Chinese would seem a most favorable opportunity for its manifestation.

In the whole series of second-generation plants there were none that even approximately represented either parent variety; nor did the plants fall into recognizable groups. With respect to the individual characters, the parental forms reappeared or were even intensified in some instances, but an almost complete and chance reassortment of the characters seems the rule. If the characters were completely independent, a reappearance of the parental types could not, of course, be expected, for, treating the characters as alternative and allowing for only 10 characters, a plant possessing all the characters of either parent could not be expected oftener than once in 10 billion plants. Although the characters themselves, with few exceptions, were non-Mendelian in the sense that they were not alternative, the results conformed to the Mendelian law of recombination. Examples of the combination of characters from the two parent varieties are shown in Plates LIX to I, XIII.

Endosperm texture was the only strictly alternative character noted. The number of erect leaves and angle of tassel, while not alternative in the sense of falling into definite groups without intermediates, do, however, approach a Mendelian form of inheritance. The distribution, instead of approximating a normal frequency curve, was distinctly bimodal with respect to these characters. A similar tendency is apparent in the first-generation plants. In connection with this evidence

of segregation in the first generation, it should be recalled that neither of these characters, which belong to the Waxy Chinese variety, is universally present in the plants of that variety, and the parent plant may have been heterozygous. There is also a less pronounced indication in the second-generation plants that one-sidedness is Mendelian in its inheritance.

CORRELATIONS

Eleven of the characters most definitely contrasted in the parents were selected and the correlation coefficients between all possible combinations were calculated for both the first and second-generation plants. The results are shown in Table IV. The correlations are so stated that a positive, or plus, correlation indicates a correlation between the characters derived from the same parent; in other words, a coherence. For example, the Waxy Chinese variety has a large number of tassel branches and no tuberculate hairs, while the Esperanza variety has a small number of tassel branches and well-developed tuberculate hairs. In expressing the relation between these two characters, when a large number of tassel branches is found associated with short tuberculate hairs, the correlation is recorded as positive.

Since ears 1 and 2 were reciprocals and no significant differences were found between their progenies, the observed values were used directly in calculating the coefficients of correlation. Where the mean progeny of ear 3 differed from the mean of the combined progenies of ears 1 and 2 with respect to any character, all measurements in the progeny of ear 1 were multiplied by the percentage difference between the means before combining the populations in a correlation table.

The combined progenies of the three first-generation ears numbered 183 individuals. Complete notes could not be taken on all the plants, so that the number of individuals entering into the different correlation tables was reduced to from 125 to 150. Assuming all correlations that are more than 3.5 times the probable error to be worthy of consideration, an examination of Table III shows that 20 of the 55 character pairs fall into this class.¹ With three exceptions the coefficient for the character pairs of this group is 0.2 or larger. Of these 20 character pairs that may be held to show definite correlations in the second generation, 17 are positive—that is, in the nature of coherences—and 3 are negative. All but 5 of the 20 are, however, open to the suspicion of being physiological correlations, since they do not differ materially from the correlations shown for the same characters in the first generation.

The 5 character pairs that show most evidence of genetic correlation are given in Table V. Even here there are no very striking differences between the coefficients of the first and second generations, and it is by no means impossible that even here the differences may be due to chance.

¹ These coefficients are printed in bold-face type in Table IV.

TABLE IV.—Correlation coefficients

Characters.	First generation.		Second generation.	
	Coef.	P.E. ¹	Coef.	P.E. ¹
long branching space.....	0.27	0.13	0.345	0.053
large number of tassel branches.....	.30	.13	.287	.055
large number of erect blades.....	.22	.14	.346	.059
high degree of one-sidedness.....	.00	.15	.353	.056
large angle of tassel axis.....	.18	.14	.411	.050
Small exert of tassel and				
small number of sheaths with hairs.....	-.21	.13	-.109	.059
short hairs.....	-.39	.12	-.150	.060
low density of spikelets.....	-.10	.14	.015	.059
short glumes.....	-.24	.13	-.050	.059
waxy endosperm.....	...	...	-.060	.070
large number of tassel branches.....	.30	.09	.442	.045
large number of erect leaf blades.....	.29	.14	.307	.061
high degree of one-sidedness.....	-.14	.13	.234	.057
large angle of tassel axis.....	.00	.13	.170	.055
Long branching space and				
small number of sheaths with hairs.....	.00	.12	.091	.054
short hairs.....	.12	.12	.056	.055
low density of spikelets.....	.33	.21	.196	.034
short glumes.....	-.01	.12	-.188	.053
waxy endosperm.....	...	...	.242	.066
large number of erect blades.....	.11	.14	.222	.063
high degree of one-sidedness.....	.27	.12	.221	.058
large angle of tassel axis.....	.18	.21	.245	.054
Large number of tassel branches and				
small number of sheaths with hairs.....	-.38	.11	-.091	.050
short hairs.....	.25	.12	-.021	.071
low density of spikelets.....	.45	.10	.214	.054
short glumes.....	.07	.12	-.165	.054
waxy endosperm.....	...	...	.104	.061
high degree of one-sidedness.....	.17	.14	.487	.050
large angle tassel axis.....	.29	.13	.513	.047
Large number of erect leaf blades and				
small number of sheaths with hairs.....	-.21	.14	-.118	.064
short hairs.....	.17	.14	-.081	.063
low density of spikelets.....	-.18	.14	.084	.065
short glumes.....	.31	.13	.043	.065
waxy endosperm.....	...	...	.382	.060
large angle of tassel axis.....	.07	.07	.582	.040
small number of sheaths with hairs.....	-.15	.13	-.050	.059
short hairs.....	.15	.13	.068	.060
low density of spikelets.....	.36	.12	.030	.059
short glumes.....	-.08	.13	-.017	.060
waxy endosperm.....	...	...	.118	.074
small number of sheaths with hairs.....	-.23	.11	-.283	.053
short hairs.....	.01	.12	.007	.050
low density of spikelets.....	.02	.13	.123	.055
short glumes.....	.47	.10	.043	.056
waxy endosperm.....	...	...	.037	.079
Large angle tassel axis and				
long hairs.....	-.05	.12	.193	.053
low density of spikelets.....	-.01	.12	-.154	.058
short glumes.....	.21	.12	-.009	.055
waxy endosperm.....	...	...	.192	.067
Small number of sheaths with hairs and				
low density of spikelets.....	.12	.12	.027	.055
short glumes.....	-.05	.12	.013	.055
waxy endosperm.....	...	...	-.014	.060
Low density of spikelets and				
short glumes.....	-.16	.12	-.235	.052
waxy endosperm.....	...	...	.082	.068
Short glumes and waxy endosperm.....	...	...	.177	.059

¹ P. E. = probable error.

TABLE V.—Character pairs exhibiting genetic correlations

Character pair.	Coefficient of correlation.		Difference between first and second generations.	Difference + probable error.
	First generation.	Second generation.		
Small exert of tassel and one-sidedness.....	0.00 ± 0.13	0.353 ± 0.056	0.353 ± 0.160	2.2
Branching space and number of erect blades.....	-.22 ± .14	.202 ± .061	.422 ± .153	2.8
Branching space and one-sidedness.....	-.14 ± .13	.234 ± .057	.374 ± .142	2.6
Number of tassel branches and number erect.....	-.11 ± .14	.222 ± .063	.332 ± .143	2.3
Number of erect blades and one-sidedness.....	.17 ± .14	.487 ± .050	.317 ± .149	2.1

Owing to the small number of first-generation individuals and the consequent uncertainty that attaches to correlation coefficients in that generation, it is, on the other hand, possible that other correlations shown in the second-generation plants are really genetic. From this point of view, it should be noted, however, that 18 of the second-generation correlations are negative.

The possibility of a reduction of physiological correlations must also be considered. The existence of a significant positive correlation in the first generation is taken to indicate a physiological correlation between the characters. With such characters as branching space and the number of branches, the relation is obvious; indeed this relation might almost be classed as physical, since as the branching space approaches zero the number of branches must necessarily become less. There would also appear to be a necessary relation between one-sidedness and angle of the tassel axis, for a perfectly erect tassel could scarcely occur with a high degree of one-sidedness. Where correlations of this nature are lowered in the second generation, it would seem necessary to assume that this reduction is brought about by a tendency for the characters from *different* parents to reappear in the same individual, thus reducing the normal physiological correlation that exists between the characters.

The following are two such character pairs:

	First generation	Second generation	Differ- ence	$\frac{D}{P.E.}$
One-sidedness and low density of spikelets.....	0.36 ± 0.12	0.030 ± 0.059	0.330 ± 0.13	2.5
Large angle of tassel axis and short glumes.....	$.47 \pm .10$	$.043 \pm .056$	$.427 \pm .114$	3.7

It has been mentioned that with respect to both the number of erect leaf blades and the angle of tassel axis there was a tendency for the plants to fall into two groups. This raised a doubt as to the applicability of the customary "product-moment" method of calculating the correlation coefficient where these characters were involved. This group of correlations was therefore recalculated, using Pearson's biserial correlation coefficient (Pearson, 1909). Slightly different values were obtained, but no additional significant correlations were brought to light.

In the second generation the waxy and horny seed were planted separately, thus affording an opportunity for observing whether the plants from seeds having the waxy endosperm characteristic of the Waxy Chinese variety showed any preponderance of other Chinese characters. No consistent differences were apparent in the general appearance of the rows from the waxy and horny seeds. There was such great individual diversity, however, that comparison was difficult. Analysis of the measurements showed little more. The only character that showed a measurable correlation with endosperm texture was the degree to which tuberculate hairs were developed on the leaf sheaths.

Since endosperm texture is strictly alternative, while all other characters were expressed in varying degrees, the method for calculating the correlation coefficients was necessarily different for this group of character pairs. In calculating the correlations with endosperm texture Pearson's (1909) method for calculating a biserial correlation, together with Soper's (1914) formula for the probable error, were used. With a strictly alternative character such as endosperm texture, it would seem impossible to distinguish physiological from genetic correlations. Since one variety always has waxy and the other always has horny endosperm, to detect correlations with this character in the parent varieties seems out of the question. Likewise, as a result of the dominance of the horny endosperm, the seeds from which the first-generation plants were grown were all horny, and there was no opportunity to determine correlations with endosperm texture among first-generation plants.

At the time of planting it was, of course, impossible to distinguish between the seed that were pure for the horny character and those that were heterozygous. An examination of the open-pollinated ears produced by the second-generation plants grown from horny seeds made such a separation possible. All ears that produced any waxy seeds must have grown from heterozygous seeds. No correlations sufficiently large to be detected in the small number of individuals available were found between these two classes and other contrasting characters.

It may be urged that the absence of coherence in the progeny of such a diverse hybrid as the one here discussed may not prove that there is a similar lack of coherence among crossbred individuals within the variety. All maize varieties are, however, of such mixed ancestry that they are in effect hybrid progenies, and even if an exhaustive study of the inheritance of the characters of a narrow-bred variety should show the existence of coherence the results would be beside the point from a practical standpoint, for to maintain a satisfactory degree of vigor in maize a condition of mixed ancestry must be retained.

INTENSIFICATION OF CHARACTERS

The present hybrid affords an interesting sample of an intensified character. One of the peculiarities of the Waxy Chinese variety is the scorpioid top. In plants which exhibit this character the leaf blades of the upper nodes are monostichous and erect, and the tassel is curved to one side. The curving of the tassel was originally interpreted as a direct result of the monostichous arrangement and erect blades. The manner in which this complex of characters reappears in the hybrid with the Esperanza variety shows that, although always associated in pure Chinese maize, they are separable and each may be inherited independently of the others. The curved tassel supposed to be merely the result of the other characters may not only occur alone—that is, in plants with

distichous leaf blades all of which make an angle with the main axis—but the extent of the curving is much greater in some of the hybrid plants than has ever been observed in pure Waxy Chinese plants. The angle of the tassel axis had not been recorded for Waxy Chinese plants before the season of 1915, but thousands of individuals have been observed, and it can be definitely stated that no plant showed a tassel inclined as much as 90° from the perpendicular.

In 148 hybrid plants of the second generation of the hybrid there were 12 plants with the axis of the tassel inclined from the perpendicular by more than 100° and 5 plants having the angle of the tassel axis recorded as more than 145° . The phenomenon is not due to any weakness of the culm, as examples of more than 180° show (Pl. LXII); in fact, the upper part of the culm is particularly thick and rigid, a characteristic of the Chinese parent.

The positiveness of the character was well shown in some of the plants where the curving of the culm caused it to break through the upper leaf sheaths. In such plants the pendent tassels very strongly suggested the "goose neck" of certain sorghum varieties. A plant of this type is shown in Plate LXIII.

CONCLUSIONS

Two principal methods of breeding may be distinguished, depending on the manner in which selection is applied:

(1) Selection may be directed toward the isolation and propagation of desirable types of individuals. The new type may occur as an aberrant individual or as a recognizably distinct strain within the variety, but in either case it is differentiated from the stock by many characters.

(2) Selection is directed to variations of the individual characters regarding which improvement is desired.

With most crop plants the method of selecting types has been by far the most productive, but in the improvement of maize, this method has figured very little. Selection has been by characters instead of by types.

Why the isolation of types of plants has not been a factor in the improvement of maize has not been clear. Though diversities in plant characters are obvious and striking, few breeders have been able to distinguish well-defined types of plants within commercial varieties.

If recognizable types exist it must mean that groups of characters tend to appear together; in other words, the characters are correlated. The extent to which obvious characters are correlated is therefore proposed as a measure of this tendency toward the persistence of types. In the progeny of a hybrid between two very different maize varieties the results here reported show that the characters studied, instead of forming coherent groups, are almost completely independent in inheritance.

By attempting to measure the extent to which types persist by means of correlation coefficients, it is necessary to distinguish different kinds of correlations. For this purpose correlations are here classified as physical, physiological, and genetic. A method is also proposed by which physiological and genetic correlations may be distinguished.

The case studied was a hybrid between two extreme types that must have been completely isolated from very remote times. The large number of well defined characters which differentiate the varieties rendered this material exceptionally favorable for the study of coherence, by which is meant the tendency for characters associated in one of the parents of a hybrid to remain together in the later generation of the hybrid.

For the study of correlations 11 characters were selected in which the parent varieties showed little or no overlapping. The correlation coefficients of all the combinations were calculated, and of the 55 possible combinations 20 were found to exhibit significant correlations. In all but 5 of these, however, the correlations are believed to be physiological rather than genetic. In no instance was there a correlation between two characters closer than 0.5, a fact which in itself offers an explanation of the difficulty of recognizing types in maize.

This lack of coherence of characters in maize, taken with the fact that to maintain a satisfactory degree of vigor a diversified ancestry must be maintained, would appear to make the method of isolating types inapplicable to this plant. As an offset to the limitation thus imposed, advantage may be taken of the facility with which desirable characters derived from different parents can be combined.

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PLATE LV

Typical plant of the Waxy Chinese variety of maize, showing numerous tassel branches, erect leaf blades, one-sidedness, and curved tassel.

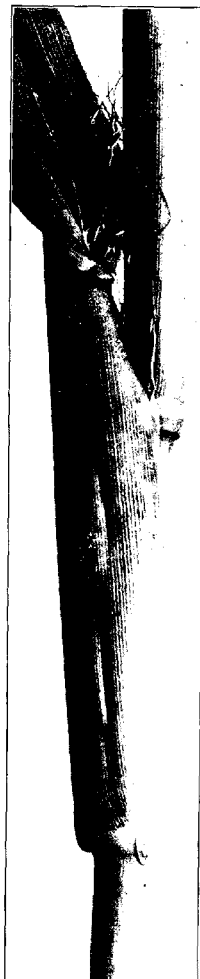
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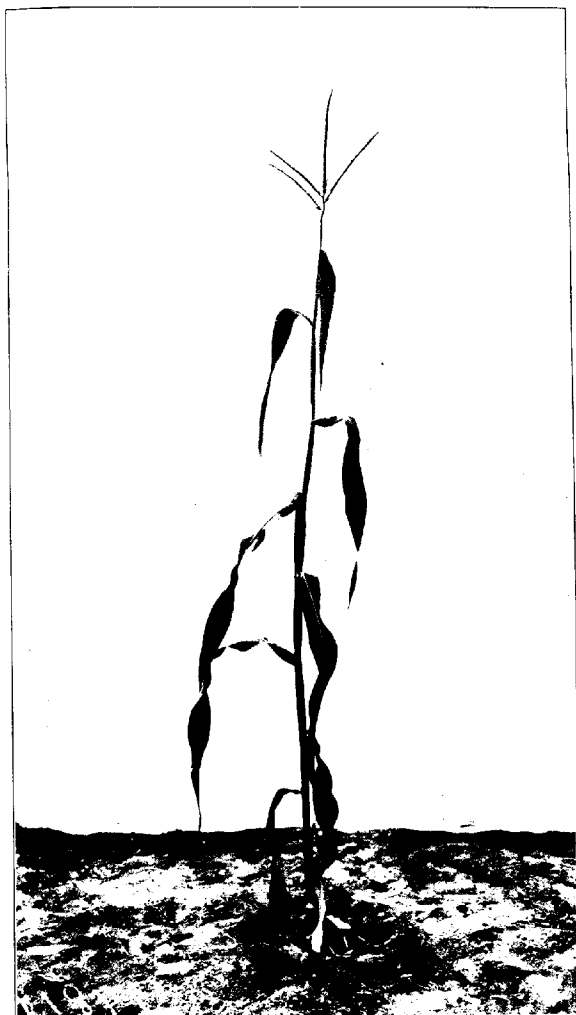
PLATE LVI

Fig. 1.—Uppermost leaf sheaths of Chinese maize plant, showing the one-sided arrangement of leaf blades and absence of hairs. Natural size.

Fig. 2.—Leaf sheath of the Waxy Chinese variety of maize, showing the transverse lines and absence of hairs. Compare with Plate LX. Natural size.

PLATE LVII

A plant of the Esperanza variety of maize, showing the drooping leaves, few tassel branches, and elongated internodes characteristic of the variety.



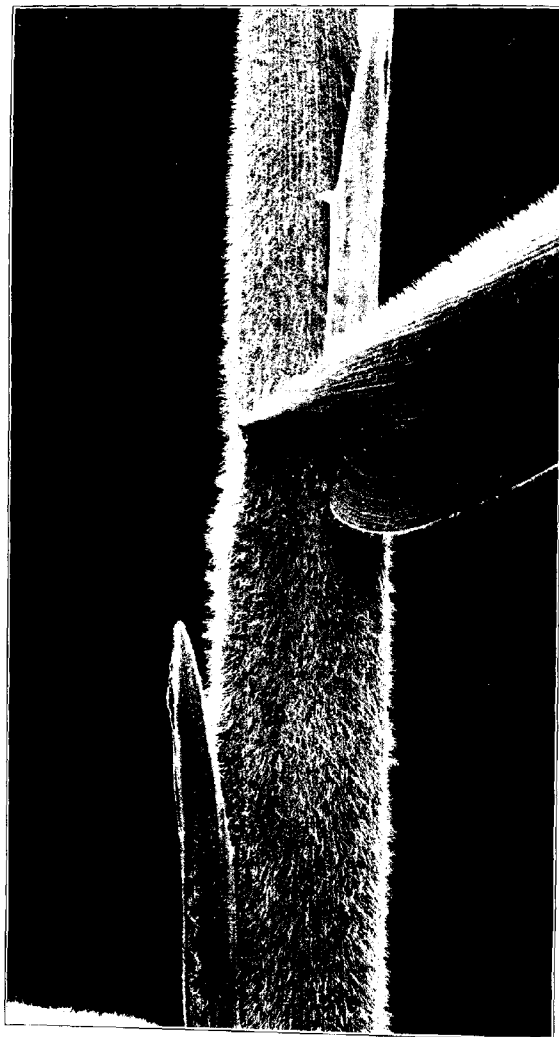


PLATE LVIII

Leaf sheaths of the Esperanza variety of maize, showing the maximum development of tuberculate hairs. Compare with Plate LVI. Natural size.

PLATE LIX

A leaf sheath of a second-generation hybrid maize plant. This plant represents the maximum length of hairs. They are even longer than any thus far observed in the Esperanza variety. Compare with Plate LX. Natural size.





PLATE LX

A first-generation plant of Chinese×Esperanza maize hybrid. Measured by the number of sheaths with hairs, this was the most hairy plant in the first generation. Combined with this Esperanza character is an accentuation of the Chinese character of a scorpioid top.

PLATE LXI

A second-generation plant of a Chinese×Esperanza maize hybrid. This plant showed a maximum development of the Esperanza character of hairiness combined with the erect crowded leaf blades and deflexed tassel of the Chinese variety.





PLATE LXII

A second-generation plant of a Chinese \times Esperanza maize hybrid. An extreme example of the scorpioid top; the angle was recorded as 190° .

PLATE LXIII

A second-generation plant of a maize hybrid, showing the "goose-neck" character that appeared for the first time in this hybrid. This plant showed few *Esperanza* characters. Although the plant is one-sided, it shows that the displacement of the tassel is not the result of crowding by the leaf blades.



COMPARATIVE STUDY OF THE AMOUNT OF FOOD EATEN BY PARASITIZED AND NONPARASITIZED LARVÆ OF *CIRPHIS UNIPUNCTA*

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INTRODUCTION

The aim of an experiment which was conducted at the United States Entomological Laboratory in West La Fayette, Ind., during the summer of 1915, was to determine whether larvæ of the army worm (*Heliothrips*) *Cirphis unipuncta* Haworth, when attacked by an internal parasite, *Apanteles militaris* Say, ate less, as much as, or were stimulated to eat more than when nonparasitized; and as a sequence, to determine whether this or a similar parasitism is directly beneficial in the generation parasitized or only indirectly, resulting in subsequent smaller generations. Although only 9 of the 25 parasitized larvæ with which the experiment was started lived until the emergence of the parasites, the others dying soon after oviposition took place, the records of these 9 larvæ are sufficiently definite to satisfy the purpose of the experiment.

The excellent work of Mr. J. J. Davis and Mr. A. F. Satterthwait¹ in determining the total amount of food eaten by healthy larvæ of *C. unipuncta* under different feeding conditions has been used to compare with the amount of food eaten by parasitized larvæ.

The results of the experiments have been drawn up in tabular form to show the life of the host larvæ from the time they were oviposited in until their death coincident with the emergence of the parasite and the life history of the parasite in relation to its host (Table I).²

EXPERIMENTAL METHODS

The parasites were induced to oviposit in the host larva while confined in test tubes into which a larva was introduced and left until recognized as a host and parasitized. Often this occurred immediately, and three or four ovipositions might take place before the larva could be removed. In other cases it would be some minutes before the parasite could be induced to oviposit.

These parasitized larvæ were confined separately in large vials, placed in the shade in a well-aired room, and fed pieces of mature corn leaves, conveniently cut out so as to measure 1 square inch each.

In order to obtain unfertilized females, individual cocoons were placed in gelatin medicine capsules previous to the emergence of the adults, the sex being easily determined through the transparent gelatin, when the adults emerged.

¹ Data as yet unpublished; may appear in a later issue of this Journal.

² The author was ably assisted in the care and feeding of the larvæ by Mr. H. J. Hart, who was temporary assistant at the laboratory during the summer of 1915.

TABLE 1.—Life-history data relating to host larvae of *Cirphis unipuncta* and to the parasites. *Apanteles militaris*, attacking them

Experiment No.	Width of head of host	Age of host postured in	Date of ovipositions.	Number of ovipositions.	Invasion of ovipositions in seconds.	Total amount of corn foliage eaten after parasitism.	Width of head of host when parasite emerged.	Age of host, when parasite emerged.	Number of parasites in each cocoon.	Date parasite spun cocoons.	Date adult parasite issued.	Time spent in host by parasite.	Time spent in cocoon by parasite.	Total life cycle of parasite.
10	Mm 2.4	Fifth instar	1915. Aug. 15, 1:34 p.m.	3+	1 each.	Sq. in. 16.21	Mm. 3.4	Sixth instar.	49	1915. Aug. 15, 10:30 a.m. to 10:30 a.m. and 6	Sept. 7, previous to 8 a.m.	13 d., 18 h., 35 m.	9 d.	23 d., 18 h., 26 m.
11	2.1	do.	Aug. 15, 1:37 p.m.	2+	1 or less each.	12.16	3	do.	39	Aug. 16, between 10:30 a.m. and 6	Sept. 8, previous to 8 a.m.	13 d., 20 h., 53 m. to 14 d., 4 h., 29 m.	9 d., 21 h., 30 m. to 9 d., 14 h.	23 d., 18 h., 23 m.
15	2.1	do.	Aug. 15, 4:30 p.m.	1	1.	11.97	do.	do.	48	Aug. 20, previous to 8 a.m.	Sept. 7, between 8 and 10 a.m.	13 d., 18 h., 10 m.	9 d. to 9 d., 3 h., 30 m.	22 d., 18 h., 10 m. to 23 d., 10 h., 10 m.
16	2.2	do.	Aug. 15, 5:04 p.m.	2+	1 each.	14.50	3.2	do.	63	do.	Sept. 7, previous to 8 a.m.	13 d., 17 h., 57 m.	10 d.	22 d., 17 h., 57 m.
19	1.8	Fourth instar.	Aug. 15, 2:55 p.m.	2	do.	20.63	3.5	do.	100	do.	Sept. 8, previous to 8 a.m.	13 d., 17 h., 5 m.	10 d.	23 d., 17 h., 5 m.
22	1.7	do.	Aug. 15, 3:06 p.m.	3	About 2 each.	17.39	do.	do.	121	do.	Sept. 8, previous to 8 a.m.	13 d., 16 h., 54 m.	10 d.	23 d., 16 h., 54 m.
23	1.8	do.	Aug. 15, 3:12 p.m.	3	do.	21.41	3.6	do.	151	Aug. 21, previous to 7 a.m.	Sept. 8, between 8 and 10:30 a.m.	13 d., 15 h., 48 m.	8 d., 1 h. to 8 d., 3 h., 30 m.	23 d., 16 h., 48 m. to 23 d., 19 h., 30 m.
24	1.8	do.	Aug. 15, 3:20 p.m.	3	do.	17.64	3.4	do.	88	Aug. 22, previous to 8 a.m.	Sept. 8, previous to 8 a.m.	13 d., 16 h., 40 m.	10 d.	23 d., 16 h., 40 m.
25	1.7	do.	Aug. 15, 3:20 p.m.	3+	1+ each.	17.99	3.5	do.	98	Aug. 22, previous to 8 a.m.	Sept. 9, previous to 8 a.m.	14 d., 16 h., 40 m.	10 d.	24 d., 16 h., 30 m.
Average												14 d., 12½ m.	9 d., 8 h., 43 m.	23 d., 12 h., 26 m.

LIFE CYCLE OF THE PARASITE

The biology of *A. militaris* has already been studied and the results published.¹

Oviposition took place with great rapidity and apparently anywhere in the host, attempts even being made by the parasite to oviposit in the head. The largest number of eggs inserted at one time, according to the observations herein recorded, was 154 for 3 ovipositions, averaging 51 + each (Table I, Experiment 23). The two endoparasitic stages and the egg stage required an average of 14 days, 11 ½ minutes, while the time spent by the third larval stage and the pupal stage in the cocoon averaged 9 days, 8 hours, and 45 minutes, and the average for the total life cycle was 23 days, 12 hours, and 26 minutes.

The parasitic larva leaves its host by means of an individual exit hole cut through the muscles and epidermis by its mandibles. As the larvæ squeeze through the holes they molt their second larval skins, and when about two-thirds of their way out commence to spin their cocoons. After the cocoon is spun and previous to pupation, the accumulated wastes are passed, being deposited at one end of the cocoon. Shortly following this the larva pupates and the last larval skin is pushed to the same end of the cocoon.

The adult issues, after kicking off its pupal skin, by cutting off a cap-like portion at one end of the cocoon, cleans itself, and at the same time passes a quantity of waste. It is now ready for copulation, oviposition, or feeding, as the case may be. In this respect it was found that females were at once ready to oviposit following emergence and previous to feeding or copulation, and that the progeny from such females were all males. Hence it is seen that unfertilized females give rise parthenogenetically to a generation of males.

CONCLUSIONS

In using the data compiled by Davis and Satterthwait on the amount of food eaten by healthy larvæ of *C. unipuncta*, for comparison with the amount eaten by parasitized larvæ, it will only be necessary to use the feeding records for the last three instars in one series of their experiments, this being the one in which the larvæ were confined in lantern-globe cages. These records were selected in preference to those obtained by keeping the larvæ in large vials, because in the former case a larger number of records were obtained, although in the latter case the averages of the feeding records for the same periods run higher.

Larvæ 10, 11, 15, and 16 were newly molted fifth-stage specimens when oviposited in, and they ate 16.21, 12.16, 11.97, and 14.50 square inches of corn foliage, respectively, during their last two stages previous to the emergence of the parasites, which is a much smaller amount than

¹ Tower, D. G. Biology of *Apanteles militaris*. In Jour. Agr. Research, v. 5, no. 12, p. 495-508, 1 fig., pl. 50. 1915.

the average of 33.6 square inches eaten by 20 nonparasitized larvæ during the same stages. Larvæ 19, 22, 23, 24, and 25 were partially developed fourth-stage specimens when oviposited in, and they ate, during the remainder of their life, which lasted until the parasites emerged from them some time during the last or sixth stage, 20.63, 17.36, 21.41, 17.64, and 17.99 square inches of corn leaf, respectively, as compared with the average of 34.77 square inches eaten by 20 nonparasitized larvæ during the last three stages. (See Table I.)

From these results it will be seen that parasitized larvæ ate approximately half as much as unparasitized larvæ during the same periods, and it seems conclusive, even from these few records, that parasitism by *A. militaris* is directly beneficial in the generation attacked. From the results obtained it might seem as though larvæ oviposited in at an earlier date would eat more before being killed, but the time spent in the host by the parasites seems to be fairly constant, and this was also noticed in a larger number of cases in former experiments with *A. militaris*. Hence, it is believed that in such cases the larvæ would have only approximately the same amount of time for feeding, and a larger portion of this period would occur during the earlier stages, when a much smaller amount of food is eaten, so that the amount eaten would be less than the normal for unparasitized larvæ.

ALEYRODIDAE, OR WHITE FLIES ATTACKING THE ORANGE, WITH DESCRIPTIONS OF THREE NEW SPECIES OF ECONOMIC IMPORTANCE

By A. L. QUAINANCE, *Entomologist in Charge of Deciduous Fruit Insect Investigations*, and A. C. BAKER, *Entomological Assistant, Bureau of Entomology*

Thirteen species of so-called white flies are recorded in literature as infesting Citrus plants in different parts of the world. Eight of these are present in Florida, four of them being native to the United States and four having been introduced. The native forms have thus far been of little economic importance, whereas two of the introduced species are first-class Citrus pests. The remaining two introduced forms, although recently established on the orange (*Citrus aurantiaca*), have already attracted attention by reason of their injuries. Our knowledge of the remaining five species of Citrus white flies, while meager, indicates that these, in their range of distribution, are abundant and destructive and would in all probability prove to be very undesirable immigrants. The new forms treated herein must be classed in the same category, especially *Aleurocanthus woglumi*, which, although previously named, is here technically described for the first time. This last species, of oriental origin, has already found its way to Jamaica and the Bahamas, where it infests the orange to a serious extent.

The present paper brings together the essential information concerning the distribution and food plants of the white flies which attack Citrus plants and describes three new species of economic importance.

Aleurocanthus citricolus (Newstead)

Aleurodes citricola Newst., 1911, in Mitt. Zool. Mus. Berlin, Bd. 5, Heft 2, p. 173.¹

This species is known only from the original description. It was taken at Dar es Salaam, German East Africa, on *Citrus* sp. in 1902. The immature stages occurred in large, overcrowded colonies, appearing to the unaided eye as patches of a sootlike deposit on the lower surface of the leaves. This is one of the spiny forms and bears a general resemblance to *A. woglumi* (fig. 2, A-J, Pl. LXIV, LXV).

Aleurocanthus citriperdus, n. sp.

This insect (fig. 1) was taken by Mr. R. S. Woglum, of the Bureau of Entomology, in several localities in the Orient, as follows: Royal Botanic Gardens, Ceylon, on an unknown tree, October, 1910; Lahore, India, on *Citrus* sp., July, 1911; Buitenzorg, Java, on orange, January, 1911; Sandan Glaya, Java, on *Citrus* sp., January, 1911. It is reported

¹ All bibliographic citations in synonymy are given in full in "Literature cited," pp. 471-472.

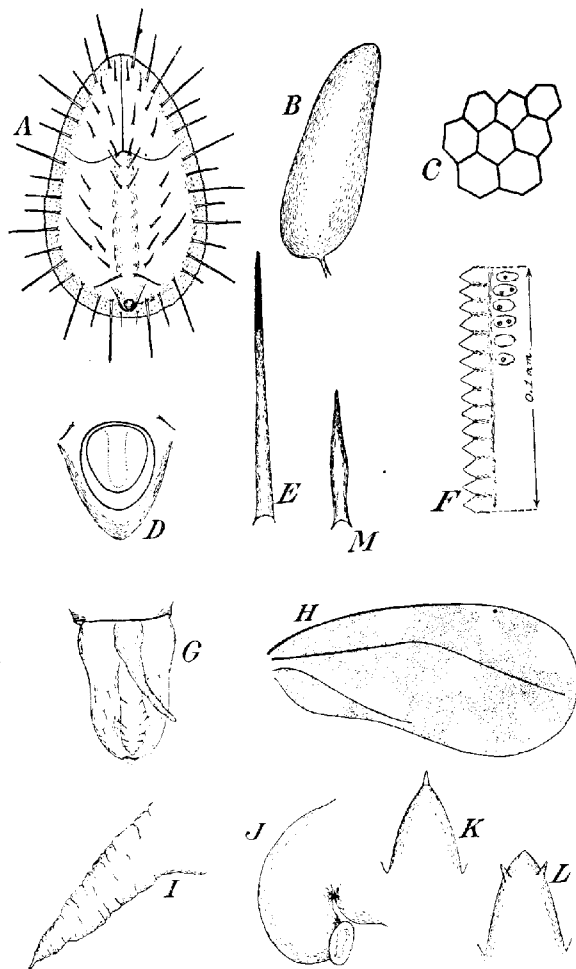


FIG. 1.—*Aleurocanthus citripendulæ*: A, Pupa case; B, egg; C, polygonal markings of egg; D, vasiiform orifice of pupa case; E, spine from dorsum of pupa case; F, margin of pupa case; G, genitalia of adult male; H, forewing of male; I, antenna of pupa case; J, leg of pupa case; K, L, marginal teeth, much enlarged; M, central swollen spine from dorsal area.

as occurring abundantly on species of Citrus and is regarded as of considerable economic importance.

PUPA CASE (fig. 1, A).—Length 1.36 mm.; width 0.96 mm.; shape elliptical to oval, broadest across the third abdominal segment, narrowest cephalad. Dorsum with a moderate central abdominal ridge on which the abdominal segments are not distinctly marked off, though they may be distinguished. Submarginal area somewhat flat; suture separating the thorax and abdomen quite distinct; surface appearing somewhat granular or faintly corrugated, an appearance which may be due to difference in pigmentation. Dorsum with numerous heavy spines (fig. 1, E) which after clearing remain black at the tips, but are otherwise a clear greenish yellow. These are arranged as follows: On the submarginal area is a more or less even row of usually 32 spines. This row is composed of two series alternating with one another. The one is made up of spines averaging about 0.288 mm., and the other of spines averaging 0.192 mm. in length. Near the medio-dorsal abdominal line there are three pairs of spines, one pair situated about 0.19 mm. anterior to the vasiform orifice and the others on the cephalic part of the abdominal region. The spines of the pair on the first abdominal segment are somewhat more widely separated than those of the other two pairs. Six other pairs of spines are present on the abdomen. Five of these pairs are short, about 0.08 mm. long, and form an even subdorsal row on each side, the rows thus formed diverging on the cephalic part of the abdomen. The remaining pair is composed of much longer spines, situated about 0.29 mm. from the thoracic suture and about the same distance from the lateral margin of the case. On the thorax there is a subdorsal row of four spines on each side (fig. 1, M) and near the medio-dorsal line another pair of spines is present. Just anterior to the vasiform orifice a pair of tubercled setae is situated, and another pair is present on the medio-caudal portion of case. The margin of the case (fig. 1, F) is dentate, the teeth (fig. 1, K, L) being rather fine and acute. A distance of 0.16 mm. is occupied by twelve of the teeth. At the base of the teeth small clear areas are found, and some distance in from the margin a row of elliptical areas, possibly glands, are present. These appear to be on the under surface of the case, while on the submarginal dorsal region, scattered between the margin and the insertion of the spines, are small dark pores. The vasiform orifice is situated on a tubercle which forms the caudal portion of the medio-dorsal ridge. It is sub-circular in outline, tending to cordate. The operculum is somewhat similar in shape and obscures the lingula. The color of cleared specimens under the microscope is a light brown, with the margin and the borders of the dorsal ridge darker.

On the leaf the cases are shining black. There is little or no dorsal secretion, but a short, white, waxy marginal fringe is present. The rods forming this fringe are not distinct, but are more or less frayed and give a woolly appearance to the outer edge of the fringe. In some specimens, however, this woolly appearance is not evident, but the wax forms a series of marginal plates. When the pupae are removed from the leaf, their former position is marked by the white oval wax ring which remains attached to the leaf. The larvae present a similar appearance on the leaf, but are brown instead of black.

ADULT MALE.—Length 0.96 mm.; general color brownish, shaded with dusky. Vertex rounded, with a longitudinal median ridge, color dark brown; ocelli clear; compound eyes Vandyke, constricted; antennae absent in the specimens at hand; labium tipped with dusky; thorax shaded with dusky. Forewings 0.83 mm. long by 0.35 mm. wide, marked with dark bluish gray, as indicated in fig. 1, H. Veins olive color; radial sector bent caudad at 0.4 mm. from the distal end. Hind wings 0.64 mm. long and 0.25 mm. wide at widest part; color uniform dusky, vein olive color. Legs with the femora and the proximal half of the tibiae dusky, the remainder of the tibiae and the tarsi greenish yellow. Fore femora 0.19 mm.; fore tibiae 0.23 mm.; fore tarsi, proximal segment 0.08 mm., distal 0.064 mm.; middle femora 0.24 mm.,

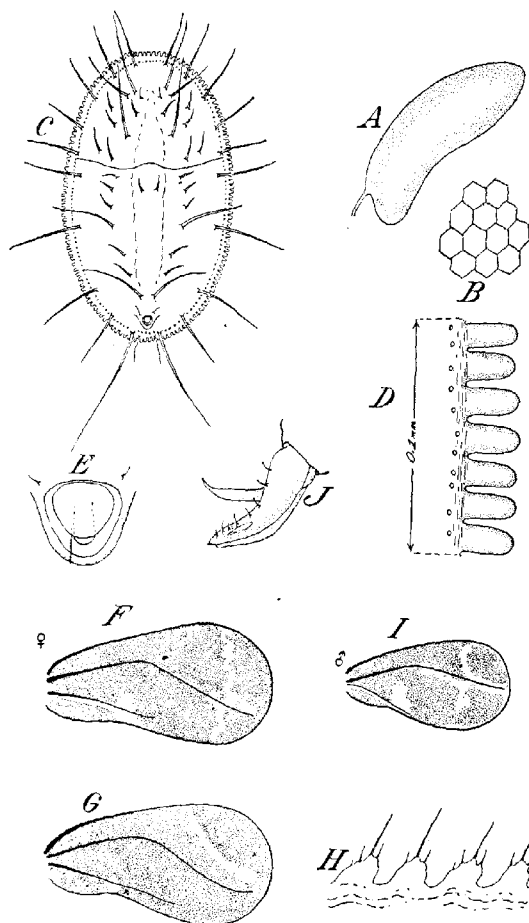


FIG. 2.—*Aleurocanthus woglumi*: A, egg; B, polygonal markings of egg; C, pupa case; D, margin of pupa case; E, vasiliform orifice of pupa case; F, forewing of adult female; G, same, showing variation in markings; H, costal margin at base of wing of female; I, forewing of male; J, male genitalia.

hind tibiae 0.36 mm., hind tarsus, proximal 0.112 mm., distal 0.72 mm. Claws normal, with a hairy central paronychium; genital segment dark brown, 0.112 mm., broad at the insertion of the claspers. These latter are dark-brown, becoming lighter at their distal tips. They are 0.128 mm. long and each about 0.03 mm. at the shoulder near the base. They are acute at the tips, curved inward, and armed on the inner margin with a number of prominent spines (fig. 1, G). A few small hairs are scattered here and there, situated on small tubercles. The penis is as long as the claspers, somewhat bulbous at the base, greenish yellow, and slightly curved upward.

ADULT FEMALE.—Unknown.

Described from adult males in balsam mounts and numerous pupa cases in balsam mounts and dry upon the foliage.

Type.—Cat. No. 19099, U. S. National Museum.

***Aleurocanthus woglumi* Ashby.¹**

Aleurocanthus woglumi Quain., Ashby, 1915, in Ann. Rpt. Dept. Agr. Jamaica, 1914/15, p. 31.

Aleurocanthus woglumi Quain., Ashby, 1915, in Bul. Dept. Agr. Jamaica, n. s. v. 2, no. 8, p. 322.

Specimens of this species (fig. 2; Pl. LXIV, LXV), which may be called the "spiny Citrus white fly," were first received by the Bureau of Entomology on June 16, 1910, from Dr. E. W. Berger, the material coming from India from H. Maxwell-Lefroy. Specimens were also received in 1910 from Mr. George Compere, who had collected the insect in the Philippine Islands. During 1910 and 1911 Mr. R. S. Woglum, in the course of his search for parasites of the orange white fly (*Dialeurodes citri* Ashm.), found this insect common and widely distributed on orange in India and Ceylon, and it has subsequently been received from that region from Mr. A. Rutherford.

Our first knowledge of its presence in the Western Hemisphere came with the receipt of specimens from Col. C. Kitchener, Half Way (Kingston), Jamaica, on November 27, 1913. Additional material was received during 1914 from Jamaica from Col. Kitchener and from Prof. S. F. Ashby, Microbiologist of the Jamaica Department of Agriculture. Under date of February 5, 1916, specimens were submitted by Mr. P. Cardin, Entomologist of the Cuba Agricultural Experiment Station, for verification of determination made by Prof. Ashby. On February 7, 1916, a large lot of orange leaves infested with *A. woglumi* was received from Mr. L. J. K. Brace, Nassau, New Province, Bahamas, who states:

Certain orchards in this island at least have been very much affected with this insect, all of the leaves being so much infested on their undersurfaces that they present a black appearance, not only killing the trees but causing some persons to attempt to stop the mischief by cutting down the trees, though the young shoots become again covered * * *. I have no doubt that the planters' exchange have introduced this pest from the East. Plants have been for some time obtained by individuals here from the Jamaican establishment and also from Florida.

Prof. Ashby thinks the insect was introduced into Jamaica on the mango during the last 20 years. In that island it has become very

¹ *Aleurocanthus woglumi*, the writers' manuscript name for this species, was furnished to Prof. Ashby. According to the International Code, his descriptive remarks, as cited, make him the author of the species.

prominent, infesting the leaves of all species of Citrus on the lowland plains. Honeydew is excreted in small amounts, which is followed by the development of sooty fungi, but not to the extent that is true of certain other white flies and scale insects.

The present known distribution and food plants are shown in Table I.

TABLE I.—Present known distribution and food plants of *Aleurocanthus woglumi*

Date.	Quaintance No.	Locality.	Host plant.	Collector.
June 16, 1910	5564	India.....	Orange.....	Maxwell-Lefroy.
1910.....	5593	Manila, P. I.....	do.....	George Compere.
1910.....	5704	do.....	do.....	Do.
Oct., 1910.....	6750	Royal Bot. Gardens, Ceylon.	<i>Capparis roxburghii</i>	R. S. Woglum.
Do.....	6744	do.....	<i>Capparis pedunculatus</i>	Do.
(?).....	6553	India.....	Unknown tree.....	Do.
Nov., 1910.....	6560	Lahore, India.....	<i>Citrus</i> sp.....	Do.
Do.....	6564	Coppanwala, India.....	do.....	Do.
Do.....	6557	Lahore, India.....	do.....	Do.
Do.....	6566	do.....	do.....	Do.
Dec., 1910.....	6558	Kalimpang, Sikkim, India.....	do.....	Do.
June, 1911.....	8011	Lahore, India.....	<i>Citrus</i> sp. and <i>Morus</i> sp.....	Do.
Sept., 1911.....	8012	Nagpur, C. P., India.....	(?).....	Do.
Aug., 1913.....	8753	Peradeniya, Ceylon.....	<i>Salacia reticulata</i>	A. Rutherford.
Sept., 1913.....	8768	do.....	<i>Kurrimia zeylanica</i>	Do.
Nov., 1912.....	8748	Half Way, Jamaica.....	Orange.....	Col. C. Kitchener.
Feb., 1914.....	8752	do.....	do.....	Do.
May, 1914.....	8922	Kingston, Jamaica.....	<i>Citrus</i> sp.; <i>Guaiacum officinale</i> ; <i>Cestrum nocturnum</i> L.....	S. F. Ashby.
Feb., 1916.....	12066	Guantanamo, Cuba.....	Orange.....	P. Cardin.
Do.....	12067	Nassau, N. P., Bahama.....	do.....	L. J. K. Brace.

EGG (fig. 2, A).—Size, 0.208 mm. by 0.08 mm.; shape elliptical, curved, with the stalk short and attached some distance from the base. Color yellowish, surface apparently without reticulations in some cases and with them in others, which is no doubt due to the structure being destroyed in boiling. When they are present (fig. 2, B) they average 0.006 mm. in diameter.

LARVA.—Larvæ are present in the material at hand, but they are in too poor a condition for accurate description. They are brown in color and armed with numerous long spines.

PUPA CASE (fig. 2, C).—Size variable in the different lots of material, averaging 1.4 by 0.89 mm.; shape regularly elliptical, with the dorsum considerably arched or rounded; the median ridge high, but not markedly distinct from the dorsal area, excepting near the caudal portion of the abdomen and at the vasiform orifice, which is elevated into a more or less prominent tubercle. Color dense black, so much so that it is almost impossible, even after prolonged boiling, to make out details. When the denser dorsal portion of the case is removed the ventral part appears under the microscope as dark brown and more or less irregularly mottled. Submarginal area with usually 20 spines forming a ring. These vary considerably in length, but the caudal pair is nearly always the longest. The spines are curved outward. A pair of hairs is present on the caudal margin caudad of the vasiform orifice. The spines on the dorsum are small excepting two pairs on the abdomen and three pairs on the thorax. Their number and arrangement are shown in the figure. The vasiform orifice (fig. 2, E) is prominent, being on a tubercle, but is small. It is somewhat triangular in shape, tending to circular. The operculum almost entirely fills the orifice obscuring the lingula—all but a very small portion at the tip. Cephalad of the orifice a pair of minute setæ is situated one on each side. The margin of the case

is dentate, the teeth large and bluntly rounded (fig. 2, *D*). The inner spaces are not acute, but often squarely truncate. A space of 0.1 mm. is occupied by six or seven teeth. On this feature alone the case is easily separable from those of the other species. At the base of the teeth, forming a ring around the case, is a series of minute, clear, porelike areas. On the leaf the case is jet black with the dorsum somewhat arched and the abdominal segments marked, but not distinctly separated. On the margin all around is a narrow cottony lateral wax fringe. This sometimes extends mesad, irregularly covering the submarginal area, but dorsal secretion is usually absent.

ADULT FEMALE.—Length from vertex to tip of ovipositor, 1.12 mm.; color brown, under the microscope a deep wine color with darker shadings on head, thorax, and tip of abdomen. The specimens at hand are somewhat imperfect and it is difficult to make out the structure. The vertex seems to be rounded and possessed of a slight median ridge. The eyes are very dark brown. The antennae are absent from the specimens at hand. Labium yellowish, tipped with black. Legs yellowish, shaded on femora with dusky. The femora and tibiae of the hind legs are considerably darker than the others; length of hind femora 0.288 mm.; hind tibiae 0.432 mm. The tarsi have the proximal segment 0.1 mm. and the distal 0.06 mm. The proximal segment is armed on its distal extremity with one large spine and several smaller ones; the foot is normal, with the paronychium straight and hairy. The forewings (figs. 2, *F*, *G*) are 1.268 mm. long and 0.76 mm. wide at the widest part. The radial sector is heavy, yellowish brown in color, and much curved. The cubitus is very fine, long and slightly curved, that portion of the wing below it forming a more or less distinct lobe. In color the wing is a deep smoky, excepting as follows: A line following the cubitus, and a rather large spot near its distal extremity are colorless. A line following the radial sector from its distal extremity to almost its median curve, and another crossing it almost at right angles are colorless. This gives the appearance of a white cross on a dark background. In some wings the marking is not so evident, but there is one curved colorless line angling across the wing a short distance above and parallel with the radial sector. The border of this white line seems more heavily shaded than the remainder of the wing. The margin of the wing (fig. 2, *H*) is armed with a series of rather prominent teeth directed toward the distal extremity of the wing. Each one of these is armed with one prominent spine and usually three smaller ones. The margin formed by these teeth and a line along their bases is bright wine red. The hind wing is uniform smoky, with the vein yellowish brown.

ADULT MALE.—Much smaller than the female, measuring only about 0.79 mm. from vertex to tip of claspers. The specimens are in poor condition, the antennae are absent, and it is impossible to make out the structure with certainty. The color is a yellowish or a reddish brown. The hind femora, 0.24 mm. and the hind tibia, 0.4 mm. in length. They are marked as in the female. The claspers (fig. 2, *J*) are 0.126 mm. long. Near their distal ends there are a number of jagged teeth and they are armed with a number of long slightly curved hairs, those near the tip being the longest. The penis is as long as the claspers, yellowish, and almost straight.

Described from females, males, and pupa cases in balsam mounts and pupa cases and eggs on the leaves.

***Aleurocanthus spiniferus* (Quaintance)**

Aleurodes spinifera Quaint., 1903, in *Canad. Ent.*, v. 35, no. 3, p. 63.

Collected on *Citrus* sp. and rose by Mr. C. L. Marlatt, of the Bureau of Entomology, at Garalt, Java, on December 7, 1901; also taken on orange at Macao, South China, by Mr. R. S. Woglum, in February, 1911.

***Aleurolobus mariatti* (Quaintance)**

Aleurodes mariatti Quain., 1903, in *Canad. Ent.*, v. 35, no. 3, p. 61.

This species (Pl. LXVI, fig. 3) was collected by Mr. C. L. Marlatt on May 17, 1901, at Kumamoto, Japan, on orange; also by Mr. R. S. Woglum on *Citrus* sp. and *Morus* sp. at Lahore, India; also collected by Mr. Woglum on *Ficus* sp. in the Royal Botanic Gardens, Ceylon; on an unknown tree in the Botanic Gardens, Buitenzorg, Java. This insect has also been received by the Bureau of Entomology from Mr. S. I. Kuwana, collected at Fukuoka, Japan. Mr. Kuwana states that this same species has been collected on Rivkin Island. One lot of infested orange leaves is also in the Bureau collection from Tokyo, Japan.

***Aleurothrixus floccosus* (Maskell)**

Aleurodes floccosa Mask., 1895, in *Trans. and Proc. N. Zeal. Inst.*, v. 28 (n. s. v. 11), 1895, p. 423.
Aleurodes horridus Hempel, 1899, in *Psyché*, v. 8, no. 286, p. 394.

This species (fig. 3, H) is based on material from Jamaica on lignum-vitæ (*Guaiacum officinale*?) and was first recorded on orange by Cockerell (1902)¹ from Mexico. The insect has several color phases, ranging from clear yellow, the typical and more abundant form, to individuals with the dorsum striped with dark brown, or with the dorsal disk dark brown and the submarginal area yellow, etc.

Hempel's *A. horridus* from Brazil on guava (*Psidium guajava*) is apparently the same as *A. floccosus*. This latter differs from *A. howardi* only in the absence of a comb of teeth on the caudal margin of the vasiform orifice (fig. 3, H). Both *A. floccosus* and *A. howardi* are almost always present together on the same leaf and their food plants and distribution are practically identical. *A. floccosus* is common in the islands of the West Indies and also occurs in Florida, Mexico, British Guiana, Brazil, Argentina, Canal Zone, Chile, and Paraguay. In addition to the orange, lime, grapefruit, etc., *A. floccosus* has been taken on the sea-grape (*Coccoloba uvifera*), *Plumeria* sp., *Baccharis genistelloides*, guava, a coarse grass, and a climbing vine.

***Aleurothrixus howardi* (Quaintance)**

Aleurodes howardi Quain., 1907, U. S. Dept. Agr. Bur. Ent. [Bul.] 12, pt. 5, Tech. Ser., p. 92.

This species (fig. 3, E, J; Pl. LXVII) occurs on the same host plant and has the same distribution as *A. floccosus*. It was apparently first found in Florida by Prof. P. H. Rolfs at Miami on sea-grape, September 25, 1900, and therefore gained a foothold in that State some years previous to its discovery by Dr. E. A. Back.

***Aleurothrixus porteri*, n. sp.**

This species (fig. 3, A-D, F, G, I, K, L; Pl. LXVIII) has been received only from Chile and Brazil. The first collection was sent by Prof. T. D. A.

¹ Bibliographic citations in parentheses refer to "Literature cited," pp. 471-472.

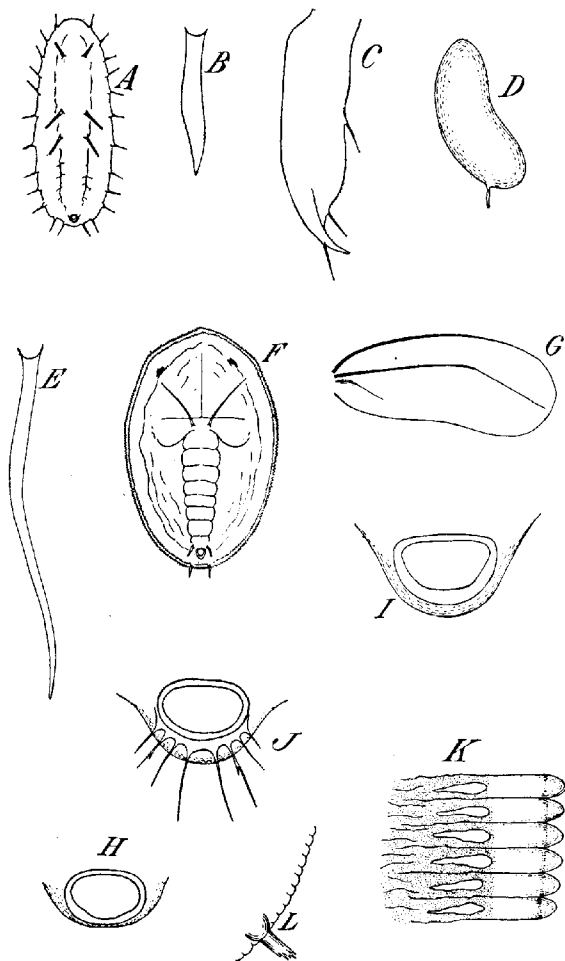


FIG. 3.—*Aleurothrixus porteri*, *A. howardi*, and *A. floccosus*: A, *Aleurothrixus porteri*: Larva, first instar. B, *A. porteri*: Caudal spine of pupa case. C, *A. porteri*: Clasper of male. D, *A. porteri*: Egg. E, *A. howardi*: Caudal spine. F, *A. porteri*: Pupa case. G, *A. porteri*: Forewing of adult. H, *A. floccosus*: Vasiiform orifice of pupa case. I, *A. porteri*: Vasiiform orifice of pupa case. J, *A. howardi*: Vasiiform orifice of pupa case. K, *A. porteri*: Margin of pupa case. L, *A. porteri*: Margin of early larva.

Cockerell on June 7, 1895, who received the material from Mr. Lataste, under the name *phalaenoides*.

In a letter to the senior author in January, 1905, Cockerell suggested that Lataste supposed the species to be Blanchard's *phalaenoides*. Since that time we have shown that *phalaenoides* Blanchard is a species of *Aleurodicus*. Table II records the distribution and food plants of the specimens of *A. porteri* in the collection of the Bureau of Entomology.

TABLE II.—Distribution and food plants of *Aleurothrix porteri* in the collection of the Bureau of Entomology

Date.	Collector.	Host.	Bureau No.	Locality.
Feb. 13, 1894.	M. Lataste	Orange.	Q. 4059	Santiago, Chile.
May 14, 1894.	do.	do.	Q. 4061	Do.
Mar. 14, 1895.	do.	(?)	Q. 4064	Chile.
Feb. 4, 1896.	Edward Reed.	Orange.	Q. 4065	Ransagua, Chile.
Apr. 1, 1899.	D. G. Fairchild.	Solanaceous plant.	Q. 457	Villa del Mar, Chile.
Oct., 1904.	M. J. Rivera	Orange?	Q. 1214	San Bernardo, Chile.
Oct. 25, 1904.	do.	<i>Schinus dependens</i> Ortega.	Q. 12022	Santiago, Chile.
June 20, 1912.	Prof. Carlos E. Porter.	<i>Schinus molle</i> .	Q. 8226	Chile.
Mar., 1913.	do.	Orange.	Q. 8890	Santiago, Chile.
Jan. 5, 1914.	Popene and Dorsett.	Jaboticaba.	Q. 12004	Rio de Janeiro, Brazil.
(?)	Prof. Carlos E. Porter.	<i>Lippia citriodora</i> Kunth.	Q. 12024	Santiago, Chile.
Aug. 9, 1915.	do.	Myrtus.	Q. 12062	Do.

Of this material, Quaintance No. 351 is chosen for the type.

LARVA, FIRST STAGE (fig. 3, A).—Size 0.352 by 0.208 mm. Shape elongate elliptical; abdomen with a moderately distinct keel, the caudal extremity of which projects to the vasiform orifice; dorsum armed with four pairs of stout straight spines; margin very minutely serrate and armed on its caudal part with a pair of long curved spines and the remainder of the margin with 11 pairs of minute spines; antennae straight, not quite as thick as the dorsal spines and extending slightly beyond the margin; vasiform orifice almost completely filled by the operculum; color under the microscope pale brown.

PUPA CASE.—Size 0.88 by 0.502 mm.; shape elliptic, some specimens slightly broader across the thorax than across the abdomen; dorsum somewhat elevated, the abdomen with a distinct keel; incisions between marginal wax tubes shallow; vasiform orifice (fig. 3, I) small, elevated, operculum filling about half of the orifice and obscuring the lingula; spines latero-cephalad of the vasiform orifice and those on the caudal margin of case short, stout, and somewhat vasiform (fig. 3, B); those on the medio dorsum long; other characters very similar to those of *A. floccosus*. Color varying from yellow to dark brown and with flocculent wax as in *A. floccosus*.

ADULT MALE.—Color yellow, eyes dark brown; clasper rather short (fig. 3, C), its spur acute and not armed within with lobes; a few prominent spines present; length 0.08 mm.; length of insect from vertex to tip of claspers 0.88 mm.; forewing 1.04 mm. long, without markings, but often uniformly clouded with dusky.

ADULT FEMALE.—Similar to male in color; length 1.12 mm.; forewing 1.28 mm.

The adults in the collection are poorly preserved, and it is impossible to describe them in detail.

Described from larva, pupa cases, and adults in balsam mounts and pupa cases upon foliage.

Type.—Cat. No. 20171, U. S. National Museum.

Bemisia giffardi (Kotinsky)

Aleyrodus giffardi Kotin., 1907, in Bd. Com. Agr. and Forest. Hawaii Div. Ent. Bul. 2, p. 94.

This insect is reported present on Citrus trees in several gardens in Honolulu, where it is stated to be so abundant that the foliage of the trees becomes blackened by the sooty fungus growing on the exuded honeydew. Mr. Kotinsky believes that the insect has been introduced into Hawaii, and this opinion is strengthened by its discovery in collections of material made by Mr. Woglum at Lahore, India, in 1911. The host, however, was an unknown tree.

Dialeurodes citri (Ashmead)¹

Aleyrodus citri Riley and Howard, 1893, in Insect Life, v. 5, no. 4, p. 219.

Aleyrodus eugeniae, var. *aurantii* Mask., 1896, in Trans. and Proc. N. Zeal. Inst., v. 28 (n. s. v. 11), 1895, p. 43¹.

Aleyrodus aurantii Ckll., 1903, in Fla. Agr. Exp. Sta. Bul. 67, p. 665.

This is the destructive Citrus white fly of Florida, where it has been known since about 1880 (Pl. LXVI, fig. 1). It is rather generally distributed over the orange-growing regions of the Gulf States and is common on chinaberry and Cape jasmine considerably north of the Citrus belt. It is also recorded from Colorado, Illinois, and the District of Columbia, where it is probably confined to conservatories. This insect was discovered in California in 1907 and serious attempts were made to effect its eradication. It is still present in one locality (Marysville), where it is now so widespread and abundant that its eradication is considered to be impracticable (Weldon, 1915).

Dialeurodes citri is undoubtedly of oriental origin. It has been received from numerous localities in India, Ceylon, Japan, China, etc. According to Kirkaldy it is present in Chile, Mexico, and Brazil. In addition to Citrus plants, the insect in Florida infests numerous others as *Melia azederach*, *Gardenia jasminoides*, *Ligustrum* spp., *Diospyros kaki*, *Diospyros virginiana*, *Syringa* sp., *Coffea arabica*, *Ficus nitida*, etc. This and nearly related species are very generally parasitized in the Orient by certain four-winged flies, which are in that region apparently effective checks on their undue increase.

Dialeurodes citrifolii (Morgan)

Aleyrodus citrifolii Morgan, 1895, La. Agr. Exp. Sta. Spec. Bul., p. 70.

Aleyrodus mufifera Berger, 1909, Fla. Agr. Exp. Sta. Bul. 97, p. 67.

Aleyrodus mufifera Mor. and Back, 1911, U. S. Dept. Agr. Bur. Ent. Bul. 92, p. 86.

This species, long confused with *D. citri*, may be readily distinguished from that species by the reticulate eggs, character of the tracheal folds of the pupa case, and the smoky patch on front wings of the adults. The insect is known from North Carolina, Mississippi, Louisiana, California,

¹ This species was first fully described by Riley and Howard in Insect Life, as cited, but had earlier been named and briefly described in The Florida Dispatch, November, 1885, by W. H. Ashmead, who, according to the rules of the International Code, must be known as the author of the species.

and Florida. While not as important as *D. citri*, it is nevertheless decidedly noxious. It is also known to occur in Cuba and Mexico. No specimens of this insect were found in the Woglum collection of white flies from India, Ceylon, and other points in the East visited by him. By reason of its affinities, *D. citrifolii* is, however, almost surely oriental in origin.

This species, with one exception, is known to attack only Citrus plants. It was found on *Ficus nitida* growing in greenhouses at Audubon Park, New Orleans, La.

***Paraleyrodes perseae* (Quaintance)**

Aleyrodes perseae Quain., 1900, U. S. Dept. Agr. Div. Ent. [Bul.] 8, Tech. Ser., p. 32.

Paraleyrodes perseae Quain. and Baker, 1913, U. S. Dept. Agr. Bur. Ent. [Bul.] 27, pt. 1, Tech. Ser., p. 83.

This species is known only from Florida, where it is frequently found on orange, though never in destructive numbers thus far. It also feeds upon *Persea*, the avocado (*Persea americana*), and doubtfully on persimmon (*Diospyros* spp.). Several species of the genus are common in the West Indies, *perseae* being the only one known from the United States.

***Trialeurodes floridensis* (Quaintance)**

Aleyrodes floridensis Quain., 1900, U. S. Dept. Agr. Bur. Ent. [Bul.] 8, Tech. Ser., p. 26.

T. floridensis has thus far been recorded by the Bureau of Entomology only from Florida, where it is rather generally distributed. It infests avocado, guava, *Annona squamosa*, and the orange. While often very numerous on guava and avocado, it is at present of no importance on orange.

***Trialeurodes vitrinellus* (Cockerell)**

Aleyrodes vitrinellus Ckll., 1903, in Ent. News, v. 14, no. 7, p. 241.

The type of this species is from Mexico on orange. Apparently the same insect has been taken in southern California on oak. Its injuries to orange in Mexico are probably not great.

***Tetraleurodes mori* (Quaintance)**

Aleyrodes mori Quain., 1899, in Canad. Ent., v. 31, no. 1, p. 1.

This indigenous species (Pl. LXIX, fig. 2) is widely distributed over the eastern United States and occurs on a large variety of plants, as mulberry, sycamore, maple, dogwood, hackberry, persimmon, holly, mountain laurel, etc. It has been found several times on orange, but not as yet in injurious numbers. That it may become troublesome under certain conditions, however, will be evident from the discussion relative to *T. mori*, var. *arizonensis*, which follows:

Tetraleurodes mori, var. arizonensis (Cockerell)

Aleyrodes mori, var. *arizonensis* Ckll., 1903, in Fla. Agr. Exp. Sta. Bul. 67, p. 666.

Aleurodes mori Ckll., 1900, in Sci. Gossip, n. s. v. 6, no. 72, p. 366.

Described from specimens taken in Arizona on orange (Pl. LXIX). The variety *T. mori arizonensis* is stated to differ from the typical *T. mori* in having the wings white marked with black without any red. An examination of the type specimens after mounting shows the presence of red markings on wings exactly as in *T. mori*, and we are unable to distinguish any characters in support of its status as a variety. On different occasions the Bureau of Entomology has received from Mexico an aleyrodid seriously infesting the orange (Pl. LXIX) which we are unable to distinguish in the immature stages from *T. mori*, and this species is considered by Cockerell to be identical with his variety *T. mori arizonensis*. While the variety, in our judgment, is invalid, we retain the name to designate a race of *T. mori* which, in Mexico, for some reason breeds abundantly on orange and is a pest of importance. *T. mori arizonensis* occurs only on orange in Mexico so far as bureau records indicate. It was first collected in 1894 by Dr. C. H. T. Townsend at Guadalajara and San Luis, and again by Townsend in 1902 at Zapotlan. Two lots of material were received from Prof. A. L. Herrera in 1905, without statement as to locality.

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PLATE LXIV

Aicurocanthus woglumi: Eggs, larvæ, and pupa cases on orange leaves.

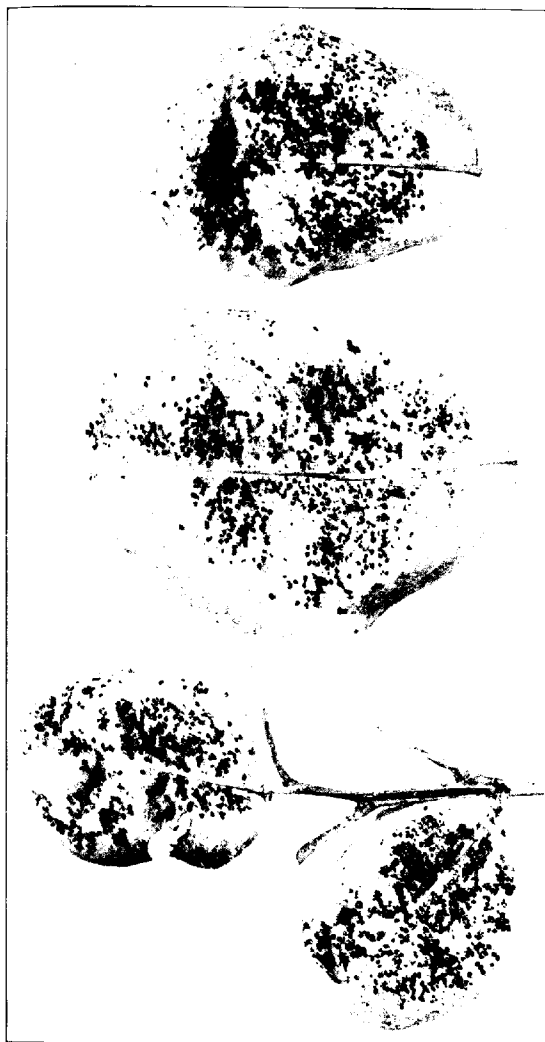




PLATE LXV

Aleurocanthus woglumi:

Fig. 1.—Colony on an orange leaf.

Fig. 2.—Eggs and pupa cases, greatly enlarged

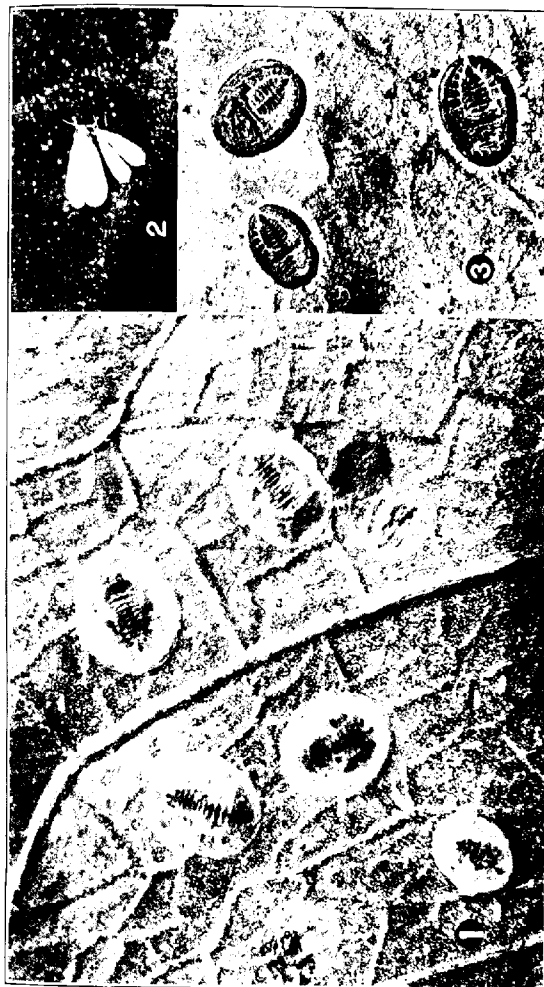
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PLATE LXVI

Fig. 1.—*Dialcurodes citri*: Pupæ, much enlarged.

Fig. 2.—Male and female adults of an aleyrodid.

Fig. 3.—*Akurolobus marlatti*, much enlarged.



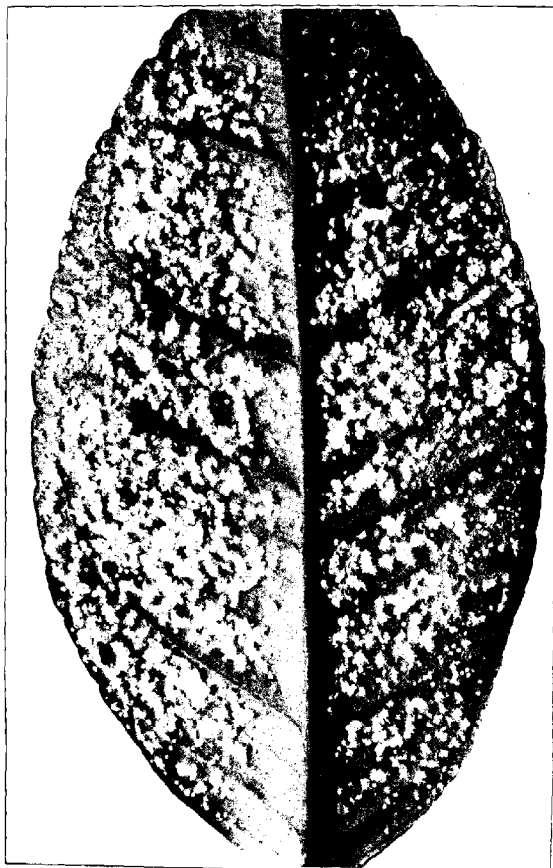


PLATE LXVII

Aleurothrixus howardi: Larvæ and pupa cases on an orange leaf, enlarged.

PLATE LXVIII

Aleurothrixus porteri: Larvæ and pupa cases on *Myrtus* sp., enlarged.





PLATE LXIX

Fig. 1.—*Tetraneurodes mori*, var *arizonensis*: Larvæ and pupa cases on an orange leaf, enlarged.

Fig. 2.—*Tetraneurodes mori*: Pupa cases on a mulberry leaf, much enlarged.

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